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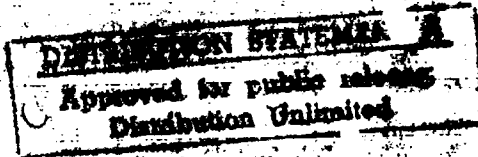
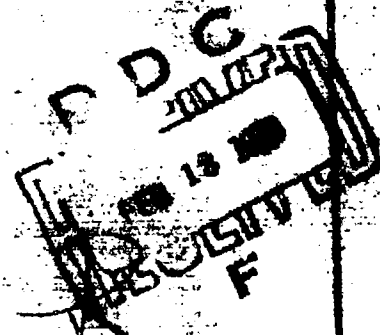


COAST GUARD

MARINE CASUALTY REPORT

M/V ELIAS; EXPLOSION AND FIRE AT FORT  
MIFFLIN, PENNSYLVANIA ON 9 APRIL 1974  
WITH LOSS OF LIFE

U.S. COAST GUARD  
MARINE BOARD OF INVESTIGATION REPORT  
AND  
COMMANDANT'S ACTION



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<p>16. Abstract - At approximately 10 P.M. on 9 April 1974 while the M/V ELIAS was in the process of completing the discharge of a full cargo of Bachaquero crude oil at the Atlantic Richfield Oil (ARCO) Terminal, Fort Mifflin, Pennsylvania on the Delaware River the vessel sustained a series of three massive explosions, burned and sank. Nine members of the crew and four visitors (relatives of the master) perished or are missing. The M/V ELIAS was a total loss and the SS EDWARD L. STEINIGER and the ARCO Terminal sustained extensive damages.</p> <p>The report contains the U. S. Coast Guard Marine Board of Investigation report and the Action taken by the Commandant to determine the probable cause of the casualty and the recommendations to prevent recurrence.</p> <p>The Commandant concurred with the Marine Board that source, and location of the initial explosion cannot be determined. Evidence of internal explosion in the after pump room, the cofferdam in the number 3 starboard cargo tanks, and in several of the cargo tanks indicate a varied path of the explosions.</p>		
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M/V ELIAS; EXPLOSION AND FIRE AT FORT  
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DEPARTMENT OF TRANSPORTATION  
UNITED STATES COAST GUARD

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16732/ELIAS  
A-3Bd

9 SEP 1977

Commandant's Action

on

The Marine Board of Investigation convened to investigate circumstances surrounding the explosion, fire, and sinking of the Greek registered tank vessel M/V ELIAS on 9 April 1974, in the Delaware River, Fort Mifflin, Delaware County, Pennsylvania with loss of life, damage to the SS EDWARD L. STEINIGER (Liberian) and damage to Atlantic Richfield Oil Transfer Terminal.

The record of the Marine Board of Investigation convened to investigate subject casualty has been reviewed; and the record, including the Findings of Fact, Conclusions and Recommendations, is approved subject to the following comments.

REMARKS

1. The ignition source and location of the initial explosion aboard the M/V ELIAS cannot be determined. The evidence of internal explosion in the after pumproom, the cofferdam in the number 3 starboard cargo tank, and in several of the cargo tanks indicates a varied path of the explosions that rocked the M/V ELIAS. Corrosion and holing was evident in drainpipes, cofferdam bulkheads, and main deck house vent systems. The location of the corroded bulkheads and drainpipes could have provided a path for combustible vapors from the number 3 starboard cargo tank to the midship house where a multitude of ignition sources were available. Similarly, the continued use of the steam heating system in the cargo tanks which could have created an ignitable vapor cloud or the failure of a steam line releasing a static charge developing spray were both potential sources of ignition. Additional secondary factors prevent the identification of any one source as the causal condition that precipitated this casualty.

2. The second sentence of paragraph 6, Finding of Fact 42, requires clarification. The point being made is that the vapors above crude oil in a cargo tank may be ignited at a lower temperature than the measured flash point of a sample of the same cargo. The reason for this anomaly is as stated - that the sample loses some of the more volatile vapors before the flash point test can be run.

3. Conclusion 6, last sentence and Conclusion 13 are disapproved. The regulation under 33 CFR 124.16 did not require the master of the ELIAS to notify the Coast Guard of the fire. The regulation places an affirmative duty upon the master, agent, or person in charge to notify the Coast Guard only if any one of them considered that the fire on the high seas and its resultant damage, if any, would jeopardize the vessel's safety or that of other vessels or facilities in port. The master, reporting a fire aboard some 100 miles at sea, requested Coast Guard assistance. Forty-four minutes later the vessel reported the fire under control and no need of assistance. As no further communication occurred between the vessel and the Coast Guard prior to its discharging in Philadelphia, it was apparently the judgment of the master that the fire at sea did not create a condition which jeopardized the vessel's safety or that of other vessels or facilities in port.

There is no legal duty imposed upon the Coast Guard to board a foreign flag vessel which has suffered a fire on the high seas. Pursuant to 33 CFR 6.19-1, the primary responsibility for assuring the safety of the vessel lies with the master, owner, operator, and agent of the vessel or waterfront facility. Apparently, the experienced officers and crew considered the vessel safe to discharge. An investigation of the fire at sea was properly the responsibility of the Greek Government since Regulation 21 of Chapter I of SOLAS 60 to which Greece is a signatory provides that "Each administration undertakes to conduct an investigation of any casualty occurring to any of its ships ..."

The Captain of the Port had personnel board the ELIAS to ascertain if damage or deficiencies resulting from the fire while at sea posed a hazardous condition jeopardizing the safety of the ELIAS or of any other vessels or facilities in the port. Observing only minor paint blistering and associated smoke damage, COTP personnel concluded there was not a hazardous condition. Coast Guard personnel also ascertained that the ship held a valid SOLAS certificate. In the absence of clear grounds for believing that the condition of the ship or its equipment did not correspond substantially with the terms of the SOLAS certificate, there was no basis for Coast Guard personnel to undertake an inspection to ascertain the condition of internal structural areas of the ship which might have uncovered the deficiencies which were later determined to have existed in the cofferdam and soil piping.

The heavy corrosion and holes in the cofferdam amounted to an inherent safety defect in the vessel and indicated that the vessel was not well maintained. The presence of doubler plates in this area would indicate

that the condition was known to the owners of the vessel. An inspection which would find such conditions could only be undertaken during a shipyard period after the tanks and cofferdam were cleaned and certified gas free. The responsibility for this condition must rest on the owners and the Government of Greece.

#### ACTION CONCERNING THE RECOMMENDATIONS

1. Recommendation. That an increase in the scope and frequency of examination of all tank vessels transferring hazardous materials in U.S. ports be initiated to ascertain if maintenance practices, operating procedures, or shipboard safety procedures as required by the current regulations are being adequately followed. Determine if the present regulations are adequately providing safeguards against hazards at terminal facilities during transfer operations.

Action. The Coast Guard presently conducts adequate inspections of United States tank vessels under the various inspection and certification statutes and the regulations promulgated pursuant thereto. The Coast Guard's authority to inspect foreign flag vessels is governed by international treaty, namely the International Convention for Safety of Life at Sea, 1960, (SOLAS 60) and related regulatory provisions delineated in 46 CFR 30.01-5(e)(1). The United States and Greece are signatory to SOLAS 60, therefore the Coast Guard must recognize certificates and documents issued under the authority of the Government of Greece as evidence that the vessel complies with the rules and regulations issued pursuant to treaty, convention, or agreement. Such certificates shall be accepted unless there are clear grounds for believing that the condition of the ship or of its equipment does not correspond substantially with the particulars of the certificates. The Coast Guard has instituted a program of more frequent boarding of foreign flag tank vessels to assure compliance with international standards and will inform the vessel's flag state of any intervention in accordance with Regulation 19 of Chapter I of SOLAS 60. The Coast Guard will board and inspect foreign vessels to insure compliance with applicable U.S. regulations contained in 33 CFR Part 155, Vessel Design and Operations and in 33 CFR Part 156, Oil Transfer Operations.

2. Recommendation. That procedures for the reporting of fire incidents onboard all inspected vessels scheduled to arrive in ports of the U.S. and while in U.S. territorial waters be initiated. The Coast Guard should establish a central house for fire source data from inputs received from all shipboard, marine transportation, and port related fire investigative reports. The central collection of information could be used to provide data and check on the effectiveness of existing statutes and regulations governing the construction of vessels, transportation, and transfer of hazardous commodities.

Action. The concept of a central clearing house for fire data is already an integral part of the Coast Guard informational system. Data on fires aboard foreign flag vessels while in the navigable waters of the

United States and those on vessels of the United States is presently available. Special incident reports for fires involving shore facilities are also available. These systems and reporting requirements are adequate.

3. Recommendation. That tank vessels carrying oil unrefined or spiked petroleum cargoes be required to be designed and operated to provide safeguard against the highest risk volatiles which may be contained within the crude oil or cargo mixture being carried.

Action. The present regulatory method for classification of flammable cargoes, design, and operation of tank vessels is considered satisfactory and accomplishes the intent of the Recommendation.

The atmosphere above a crude oil cargo in a cargo tank is a vapor mixture, predominately consisting of the lower molecular weight hydrocarbon gases found dissolved in the crude oil as well as vapors from the liquid constituents of the crude oil. The composite mixture of vapors has a distinct flash point and a distinct range of flammable limits which is both measurable and mathematically predictable. The flash point test and Reid vapor pressure test provide adequate indices of the flammability hazards although intelligent use must be made of this information.

4. Recommendation. That the wording of regulations covering visitors on tank vessels be clarified. The regulations should prohibit uninitiated persons from going aboard tank vessels and require positive supervision by ship's personnel of persons who may be permitted on board during the hazardous times of cargo transfer.

Action. The present regulations are adequate and preclude the unauthorized entry of persons on board tank vessels. Any person visiting a tank vessel is under the direct and immediate supervision of the vessel's master or other ship's officer or crew and the responsibility for his conduct and compliance with safety standards lies with the vessel.

5. Recommendation. That the sudden and massive detonation aboard the M/V ELIAS supports a recommendation that all tank vessels of significant size be fitted with an inerting system in the cargo tanks. The benefits in vessel safety to be gained by the proposed changes to the rules and regulations for tank vessels, incorporating the provision for IMCO resolution A.271 (VIII) requiring an inert gas system for the protection of cargo tanks on crude oil carriers of 100,000 DWT and crude oil combination carriers over 50,000 DWT, is supported by the findings of the board. The board, however, recommends that a gas inerting system be required on all tank vessels of over 20,000 DWT carrying crude oil cargo.

Action. The Coast Guard has regulations in effect requiring gas inerting systems for the protection of cargo tanks on crude oil carriers of 100,000 DWT and crude oil combination carriers over 50,000 DWT.

A Notice of Proposed Rulemaking has been issued which extends existing inerting requirements. The proposed regulations apply to tankships or combination carriers of 20,000 DWT or more as follows: (1) Each United States flag tankship that is certificated to carry Grades A, B, C, and D liquids; (2) Each foreign flag tank vessel engaged in the trade of carrying flammable or combustible liquids to or from a U.S. port or place. Foreign tank vessels which carry cargo that has a flash point of 65.5°C (150°F) or higher by an open cup test (Grade E) will not be required to have an inerting system.

6. Recommendation. That independent tests be conducted to evaluate the validity of laboratory flash point and Reid vapor pressure test results as a means of identifying the hazards associated with petroleum cargo and petroleum vapor characteristics as they exist in a shipboard environment.

Action. This Recommendation is not concurred with. It must be recognized that the flash point and Reid vapor pressure test are not meant to positively identify the hazards associated with petroleum cargo and petroleum vapor characteristics. These tests are used merely to classify the cargo so that a containment system can then be specified as outlined in 46 CFR 30.10-22. It must also be recognized that these tests are in wide use and relatively easy to perform.



O. W. SILER

Admiral, U. S. Coast Guard  
Commandant

9 SEP 1977





**DEPARTMENT OF TRANSPORTATION  
UNITED STATES COAST GUARD**

MAILING ADDRESS:  
U.S. COAST GUARD  
400 SEVENTH STREET SW.  
WASHINGTON, D.C. 20590  
PHONE:

5943/M/V ELIAS  
MARINE BOARD  
19 JULY 1977

From: Marine Board of Investigation  
To : Commandant (G-MI-1/83)

Subj: M/V ELIAS of Greek Registry, explosion, fire and sinking,  
9 April 1974, Delaware River, Fort Mifflin, Delaware County,  
Pennsylvania with loss of life; damage to the S/S EDWARD L.  
STEINIGER (Liberian) and damage to Atlantic Richfield Oil  
Transfer Terminal.

FINDING OF FACT

1. At approximately 2150 hours EDT on 9 April 1974 while the M/V ELIAS was moored at the Atlantic Richfield Oil (ARCO) Terminal, Fort Mifflin, Delaware County, Pennsylvania, and in the process of completing discharge of a full cargo of Bachaquero crude oil, the vessel exploded, burned and sank. Nine members of the crew and four visitors (relatives of the master) perished or are missing. Surviving crew members on board escaped from the aft section of the vessel by climbing down mooring lines or by swimming ashore. Thirteen members of the crew and one person on shore were injured and required hospitalization from injuries sustained. The casualty resulted in the total loss of the M/V ELIAS. The S/S EDWARD L. STEINIGER, which was moored upstream of the M/V ELIAS, suffered above deck damage from flying missiles and debris. Berth A and adjacent buildings of the Atlantic Richfield Terminal were extensively damaged by the blast and from large sections of hull plating of the M/V ELIAS which were hurled by the explosions.

The conduct of the investigation was hampered by the variety of dialects, technical language and the necessity of taking the witnesses testimony through an interpreter.

Salvage of the hull of the M/V ELIAS was undertaken subsequent to the submission of the original report. The original report was returned to the Board and has been amended to include the findings discovered during salvage operations. In 1977 the Board was advised of eye witnesses to the explosion from aircraft and a vessel in the area who were not known earlier. Additional testimony was taken and the report revised accordingly.

2. Vessel Data:

Name:	ELIAS
Official Number:	4849
Call Letters:	SZOP
Service:	Tank Vessel
Gross Tons:	19,178

Net Tons: 11,238  
 Length: 649' 10"  
 Breadth: 82' 0"  
 Depth: 46' 3"  
 Propulsion: Motor  
 Horsepower: 10,800  
 Home Port: Piraeus, Greece  
 Owner: Lidoriki Maritime Corp.  
 Piraeus, Greece

Operators: Eletson Maritime, Inc.  
 Piraeus, Greece

Agent: Charles Kurz Co.  
 115 Chestnut Street  
 Philadelphia, Pa.

Master: Andreas Antoniadis  
 License: Unkown  
 Last Inspection: Solas Safety Equipment Feb. 1973  
 Solas Safety Construction Feb. 1973

Classification: Germanischer Lloyd  
 Society: (Aug. 1973) last endorsement

3. The following persons lost their lives as a result of the casualty.  
 DEAD: ADDRESS:

Andreas ANTONIADIS Master

Desta GEBRHIDHIN A.B.

Matina MENTIS Visitor Age 41 415 S. Newkirk St.  
 Baltimore, Md.

Joann MENTIS Visitor Age 18 415 S. Newkirk St.  
 Baltimore, Md.

Georgeen MENTIS Visitor Age 16 415 S. Newkirk St.  
 Baltimore, Md.

Nicholaos ANDONIOU Chief Mate

Konstantinos SPETSIOTIS 3rd Mate

Elefterios STEFAS 2nd Mate

The following persons are missing:

Huseyin AXSU	A.E.		
Salama ELHADIDY	Fireman		
Enver MEHMET	Fireman		
Antonios ZABELIS	Pumpman		
Maria MENTIS	Visitor	Age 19	415 S. Newkirk St. Baltimore, Md.

The following person was injured and required hospitalization in excess of 72 hours.

William CALAFATY	Security Guard	715 E. Allegheny Ave. Philadelphia, Pa.
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4. The weather at the time of casualty was overcast with good visibility estimated at 10 miles. Air temperature was 39° Fahrenheit, with a humidity of 75%. Sea water temperature was 50° Fahrenheit. The wind was from the West Northwest at 12 miles per hour and was blowing across the M/V ELIAS from the port bow toward the starboard quarter. Low water at Fort Mifflin was predicted for 2259 EDST. The river current at the time of the casualty was ebbing. The last maximum ebb occurred at 1908 EDST at a velocity of 1.8 knots and low water slack was predicted for 2321 EDST.

5. Description of vessel:

The Motor Tanker ELIAS, with a length of 649' 10" and a beam of 82' measured 19,178 gross tons, 11,238 net tons, and a maximum summer draft of 34' 0-3/4", equivalent to a dead weight tonnage of 29,920 tons. The M/V ELIAS, formerly named the HILDA KNUDSEN while under Norwegian registry, was built in Gothenburg, Sweden, in 1956 and was transferred to Greek registry in February 1973. The vessel was constructed of steel and utilized both riveted and welded construction.

The M/V ELIAS was a twin screw motor vessel with two (2) six cylinder diesel engines with a combined rating of 10,800 B.H.P. The vessel was fitted with three (3) auxiliary "Scotch Boilers" with an operating pressure of approximately 100 psi which provided steam for cargo heating, cargo transfer and other auxiliary services.

The M/V ELIAS is a typically configured tank vessel having a raised fo'c'sle head, a midship house, and an after house. The vessel's master, deck officers and radio officer were quartered in the midship house from which the vessel was navigated. The after house contained the main machinery and provided accommodations for the other members of the crew. The vessel carried four aluminum life boats, two on the forward and two on the after deckhouses. A catwalk connected both deckhouses and also a catwalk forward provided access between the midship house and the fo'c'sle.

6. The cargo space on the M/V ELIAS was divided into six main sections and further subdivided into 23 individual cargo tanks. The center tank capacities ranged from 1273 to 1904 metric tons (M.T.) and the wing tank capacities ranged from 579 to 1863 M.T. of oil cargo. Six wing tanks, numbered 1 through 6, were located on both port and starboard sides and 11 center tanks, numbered 1 through 11, were separated from the wing tanks by two longitudinal bulkheads which extended from the forward cofferdam and ran the entire length of the tank area. The center tank, No. 1, shared a forward and aft common boundary with No. 1 wing tanks. The remaining center tanks in the space between 2, 3, 4, 5, and 6 wing tank boundaries were divided into approximately equal center tank compartments. The longitudinal bulkheads also passed through both cargo pumprooms and divided the pump room area into a main center section and two wing cofferdams.

The M/V ELIAS was equipped with three pumprooms. A forward pumproom, located just aft of the chain locker between frames 110 and 114, was used primarily to transfer bunkers.

A forward cargo pumproom was located just forward of the midship house between frame 82 1/2 and frame 84 and was situated between Nos. 2 and 3 port and starboard wing tanks and Nos. 3 and 4 center tanks.

An after cargo pumproom was located halfway between the midship house and the after deck house between frame 66 1/2 and frame 68 and situated between Nos. 4 and 5 port and starboard wing tanks and Nos. 7 and 8 center tanks.

Both cargo pumprooms were accessible only from the main deck level and each pumproom access was sheltered by a deckhouse enclosure which also contained the pumproom ventilation trunks.

The cargo pumproom machinery was contained within the main cargo pumproom space located between the longitudinal bulkheads. The outboard cofferdams were accessible by manhole openings from the cargo pumproom on the lower platform level. Cargo piping to the tanks and to the sea suction shell connections passed through the cofferdams.

The M/V ELIAS had two main cofferdams, one located just aft of the fo'c'sle head, between frames 93 and 94, which separated the forward deep tank and dry cargo hold from the forward cargo tanks. The other cofferdam located forward of the main machinery spaces, between frames 53 and 54, separated the after cargo tanks from fuel oil and ballast tanks. The cofferdams extended from the keel to the main deck and to the side shell on both sides of the vessel.

A small void or cofferdam was located in each No. 3 wing cargo tank between frames 78 and 79 which extended from the side shell to approximately 2 feet inboard of the deckhouse bulkhead on each side. The

voids housed waste drainage piping from the midship house and a man-hole provided access for maintenance of clapper valves in the drainage lines at the side shell. The lower boundary of the cofferdam extended from approximately 2 feet below the main deck at the inboard extremities to about 8 feet below the main deck at the side shell.

7. The cargo transfer system consisted of two Eureka vertical compound duplex piston reciprocating pumps rated at 750 tons per hour and one vertical duplex bilge and stripping pump rated at 200 tons per hour in each cargo pumproom. The main cargo pumps were located on a lower level of the pumprooms near the centerline. The stripping pump was located at a higher level on the starboard side of each cargo pumproom.

The main cargo pump suction lines were connected to a 15 inch cargo line and by a crossover line were connected to the 13 inch sea suction. The main cargo pump suction lines in each pumproom were inter-connected by means of a 15 inch crossover line which also connected the pumps to the 15 inch cargo line servicing the adjacent cargo loop. A 13 inch discharge line from each main pump led vertically to the main deck.

The stripping pump in each cargo pumproom was connected to the after main cargo crossover line by an 8 inch suction line. A 7 inch discharge line on the stripping pump was connected to the sea suction, the starboard main cargo line riser and to an overboard discharge located on the starboard side of the side shell above the load water line.

The main 15 inch cargo piping consisted of three individual loops separated by the two cargo pumprooms. An 11 inch line connected the suction bell of each tank to the main cargo piping. Stripping of all cargo tanks could be accomplished through the main cargo lines.

A separate 4 inch stripping line serving tanks No. 2 port, No. 2 starboard, and No. 3 center was located in the forward pumproom.

A separate 4 inch stripping line was provided in No. 4 port and starboard and No. 7 center tanks and another 6 inch line was provided in No. 6 port and starboard wing tanks and No. 11 center tank. Both stripping lines led to the after pumproom.

The 15 inch cargo piping loop in the forward section passed through No. 1 and No. 2 port and starboard wing tanks with a crossover in No. 1 and No. 3 center tanks. The cargo piping for the forward loop entered the forward pumproom through the wing cofferdams on both the port and starboard sides.

The 15 inch cargo piping in the center loop section passed through Nos. 3 and 4 port and starboard wing tanks with crossover lines in No. 5 and No. 7 center tanks. The piping entered the forward pumproom through the port and starboard longitudinal bulkheads of the main pumproom space. The cargo piping entered the after pumproom through the port and starboard wing cofferdams.

The 15 inch cargo piping loop in the after section passed through Nos. 5 and 6 port and starboard wing tanks with a crossover in No. 9 and No. 11 center tanks. The after cargo loop piping entered the after cargo pumproom through the port and starboard longitudinal bulkhead of the pumproom.

The cargo piping on the main deck consisted of two 13 inch lines located, one on either side of the center line, on the port and starboard sides and extended from the risers of the forward cargo pumproom to the deck manifold located forward of the after cargo pumproom. The cargo deck manifold consisted of three 13 inch athwartships lines forward of the after cargo pumproom and one 13 inch line aft of the pumproom.

A single 12 inch cargo line extended along the port side of the center line of the main deck from the manifold to the transom for over the stern loading and discharging.

8. The tank venting (gas line) system was of a common header type with individual pressure vacuum (P.V.) valves fitted in each branch line at each tank trunk. The branch lines, approximately 4 inches in diameter, were attached to the P.V. valve on the side of the tank trunk and led to the common header which ran the length of the vessel's cargo tank deck.

The vent header contained two vertical risers one on each mast at frames 64 and 92. The 6 inch diameter vents on the masts extended approximately 50 feet above the deck and were fitted with wire mesh type flame screens.

The pressure vacuum valves were of cast ferrous material with non-ferrous internal components and had inlet and outlets of approximately 4 inch pipe size. The pressure setting was for 1.99 psi and vacuum setting (-) .995 psi, the valve had a metal dog on the valve stem under the handwheel which permitted blocking the pressure disc off its seat in the open position. The vessel was not equipped with an inerting system for the cargo tanks.

9. The shipboard electrical distribution system was 220/110 volts D.C. with most motors on the 220 volt system.

Lighting for the main deck consisted of flood lights at frames 58, 64, 76, and 91 located at least 30 feet above the main deck. The vessel's electrical plan also indicates that lighting was installed above the centerline catwalk at frames 58, 71, and 86 and was located at least 20 feet above the main deck. Electrical wiring on the open main deck was installed in metallic conduit.

10. The electrical installation in the pumprooms consisted of explosion proof electrical lighting fixtures and associated wiring run in metallic conduit. The lighting fixtures were of a type that would have required disassembling in the pumproom for relamping. The normal shipboard practice was to defuse the circuit before relamping the pumproom lights. The location of the switches for the pumproom lights was not determined.

The electrical installation in the midship house on the main deck level consisted of explosion proof lights and metallic conduit in the storeroom areas.

The main deck part of the midship house consisted of storeroom spaces between frames 77 and 82. There were two doors in bulkhead 77 and both provided access to the compartment from the after tank deck. An interior ladder at frame 77 1/2 on the port side provided access to the deck above.

Nonexplosion proof equipment consisting of an electric powered washing machine, electric dryer, air conditioning or refrigeration compressor, gyro compass and accessory equipment, and radar power equipment using a marine type cable was installed in an enclosed compartment on the centerline in the aft section of the midship house between frames 77 and 79 1/2. The only access to this enclosed compartment was an interior ladder at frame 78 on the port side leading to the accommodation spaces above. There were two portholes in the after bulkhead of this compartment at frame 77. Whether the portholes were open was not determined. There was no cofferdam separating this compartment from the cargo tanks. The gyro compass was the only electrical equipment in operation in the enclosed space at the time of the explosion. The power supply for the gyro compass was from a motor generator (M.G.) set. The M.G. set converted 110 volt D.C. ship's power to 70 volts A.C. The motor side of the M.G. set was not rated for explosive atmospheres and contained a commutator and brushes which would produce sparks during normal operation.

11. An anodic passive type of cathodic protection equipment (sacrificial anodes) was mounted in some of the cargo tanks. The anodes were installed on brackets welded to the lower longitudinal less than 10 feet above the bottom shell. The anodes were approximately 3 feet long, 2 inches square and were generally in good condition.

12. The M/V ELIAS departed La Salinas, Venezuela, on 2 April 1974 with a cargo of 217,000 barrels of Bachaquero crude oil bound for Atlantic Richfield Co., Fort Mifflin Terminal in Delaware County, Pennsylvania. The Bachaquero crude oil cargo was very viscous and the ship's steam heating coils in the tanks were activated during the voyage.

The voyage was uneventful until 2215 hours EDST on 7 April. Charalampus Alexopoulos, A.B. while standing watch on the bridge saw flames coming from around the ullage opening of No. 3 starboard wing cargo tank. The general alarm was sounded and the crew went to their respective fire stations. About the same time smoke was observed coming from the port and starboard doors on the main deck level on the after side of the midship house at frame 77 and also from the hatchway of the lower bridge deck on the port side at frame 78. The flame from around the ullage was observed by at least six crew members at varying distances.

The closest observation was from a distance of about 30 feet as observed from overhead from the bridge wing and on the main deck. The flame was described as pulsating to a height of about 2 meters and coming from around the closed ullage opening cover, which was secured by three wing bolts. Whether the wing bolts were loose or the gasket defective was not determined. The fire at No. 3 starboard wing cargo tank was quickly extinguished by application of steam smothering to the tank through the installed system.

The smoke that emanated from the midship house was described as medium to dark in color and without distinctive odor. Crew members with charged hoses entered the midship house through the main deck doors in the after bulkhead and extinguished the fire without difficulty. Crew members' reports of flames and what was burning in the midship house is sketchy. The only indication of any fire that was noted was blistered paint on the bulkhead, soot deposits on the overhead and charred covering material on a bag of sawdust.

13. The master sent an emergency S.O.S. message indicating the M/V ELIAS had a fire onboard at 2244 hours EDST time 7 April, and that the vessel was in position as 37° 30'N. latitude, 74° 10'W. longitude. At 2328 hours, EDST time 7 April a second message was sent out cancelling the emergency. The vessel proceeded to Fort Mifflin and berthed portside to berth "A" ARCO Terminal at 1700 hours EDST on 8 April.

There were no entries concerning the fire incident made in the vessel's deck log on 7 April. Entries in the log subsequent to 7 April are obliterated by water damage and are illegible.

14. Dock personnel, after securing the vessel's mooring lines, boarded the vessel to verify tank ullages and cargo temperatures. A declaration of inspection indicating the vessel's readiness to discharge was delivered to the terminal representative by the chief mate. The ship's copy and the terminal's copy which was in the control cab on the crane rig on "A" dock were destroyed in the fire. The declaration of inspection covering those items listed in 46 CFR 35.35-20 did not contain any notations of any difficulties with the vessel's or terminal's equipment which would have affected the cargo off-loading. Two 10 inch cargo discharge hoses were connected from the ship's cargo manifold located at frame 68 to the hose rig at berth "A". A bonding cable was connected from the hose rig to a flange on the forward cargo hose on the vessel.

15. The discharge of cargo commenced at about 1730 hours on 8 April with a cargo temperature ranging between 125 to 135 degrees Fahrenheit. The steam heating system to the cargo tanks was actively being used to heat the cargo during the period of discharge. The steam to the heating coils in the tank was controlled by the deck watch using valves in the vicinity of each cargo tank.

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There were no unusual cargo handling difficulties reported or observed on deck or in the pumprooms. There was no repair work in progress on deck or in the pumproom during the discharging. Some repairs were in progress on the main engines, however, they were completed prior to the time of the explosion. The only unusual situation noted was on the evening of 8 April when the ship's crew reported that an ARCO Terminal employee was having some difficulty computing gauge capacities and allegedly engaged in an argument with the chief mate.

The M/V ELIAS received 400 tons of fuel oil and 25 tons of diesel oil from the tank barge NIAGARA which moored on the starboard side of the M/V ELIAS. Bunkering was completed at 2030 9 April without incident. The barge departed under tow for Girard Point at 2030.

16. After the vessel was cleared by U.S. Department of Immigration inspectors, one provision imposed was that two crew members (detainees) were not permitted to leave the vessel. The ship's agent engaged the services of a local guard service to check ship's personnel leaving the vessel to insure that the detainees remained on board. Prior to the casualty the guard service employee, Mr. William Calafaty, was on duty guarding the vessel from his private vehicle which was parked on a road of the terminal near the dock ramp to the vessel. The car was parked in such a manner that the guard could view both the bow and stern in addition to the gangway area of the M/V ELIAS. The vehicle was approximately 300 feet from the gangway. During the period prior to the casualty one detainee was allowed to leave the vessel under the supervision of the shore security guard to make a phone call in the guard house of ARCO Terminal. The detainee was returned aboard shortly thereafter.

17. At approximately 1330 hours on 9 April an inspector from the Marine Inspection Office, Philadelphia, Pa., visited the M/V ELIAS to inspect the areas affected by the fire of 7 April for the purpose of advising the Captain of the Port, Philadelphia, if due to the fire, the vessel would be considered a hazard to the port. The inspector, LT. Adamchak, visited the scene of the fire of 7 April accompanied by the Chief Mate, Nicholas Andoniou. They went to the storage area on the main deck of the midship house (bridgehouse) and to the cargo hatch cover of No. 3 starboard wing tank. There was no evidence of a fire in the midship house other than some blistered paint approximately 1 foot off the deck on starboard bulkhead, which covered an area 3 feet high and 1 foot wide. Soot deposits were noted on the overhead. The lighting circuits were deenergized on the main deck portion of the midship house. A broken/cracked explosion proof globe in the fire area was noted by the inspector during the tour of the midship house. An inspection of the ullage hole in No. 3 starboard wing cargo tank hatch did not reflect physical or flame damage to the ullage cover. Except for a brief visit to the salon in the midship house, this constituted the extent of the MIO inspector's inspection.

18. Shortly after 1400 on 9 April two representatives from the Captain of the Port, Philadelphia, visited the vessel to conduct an inspection to

determine if the effects of the fire at sea of 7 April constituted a hazard to the port. They also made a routine inspection to see if the vessel was in compliance with 46 CFR 30.01-5(e), 35.30, and 35.35. After conferring with LT. Adamchak and not noting any safety violations or any unusual conditions which affected the safe transfer of cargo the three Coast Guard personnel departed the vessel. While on board Coast Guard personnel noticed a vibration of the hull associated with the reciprocating cargo pumps.

19. Sometime after 1630 on 9 April the vessel's master brought four visitors aboard the vessel. They were his cousin, Mrs. Matina Mentis, and her three daughters, Maria, Joann, and Georgeen Mentis. The master and his guests were last observed in the master's cabin about 1930.

The ARCO Terminal procedures require that guests coming aboard any vessel be authorized by the master and be issued a visitor's pass. A visitor's pass for the Mentis family was deposited with the gate watch in advance of their visit, however, the Mentis family was not observed passing through the ARCO Terminal gate. The Mentis automobile, a 1967 gold colored Chevelle sedan, was discovered after the explosion to be parked on the ARCO Terminal property. The ARCO Terminal procedures normally restrict visitors on board vessel owned or chartered to Atlantic Richfield Company. The restriction of visitors is not imposed on other vessels which frequent the terminal.

20. During the day and prior to the casualty five crew members left the vessel to go ashore. The chief engineer returned to the vessel prior to the explosion and remained aboard. The radio officer went ashore about 1030 and returned at 1930. He again left at 1950 and was ashore at the time of the explosion.

21. About 1700 on 9 April miscellaneous ship stores were delivered to the vessel by a local ship chandler. The gantry crane at pier "A" was used to load the stores on board the vessel.

22. At about 2030, Mr. Calafaty, the security guard went aboard the M/V ELIAS to get his time sheets signed by the chief mate. He transacted his business with the chief mate in the chief mate's cabin and departed the vessel and returned to his car. There were no unusual occurrences or any concern expressed by any of the crew in Mr. Calafaty's presence while he was aboard and everything appeared to be progressing normally.

23. At about 2100 the terminal dockman, Mr. Vain, went aboard the vessel to the chief mate's room to check on expected time of completion of cargo discharge. The chief mate advised him that completion of discharge was expected to occur about 0200, 10 April. There were no unusual occurrences observed on board and no concern was expressed by the chief mate to the terminal dock man while he was aboard. Mr. Vain then departed the vessel and went to the guard house in the terminal building.

ARCO instructions require that the assigned dockman (second operator) be in attendance at the dock area during cargo transfer operations. Testimony reflects that Mr. Vain left the dock area and went to the guard house approximately 500 feet from the M/V ELIAS without being relieved. Normal terminal procedures provide for the dockman to request a relief when it is necessary for him to leave the dock area.

24. At about 2130, the 8-12 watch Able Seaman, C. Alexophulus, was told by the chief mate to make coffee in the officer's saloon. Alexophulus finished making coffee and poured two cups which he left in the chief mate's dayroom. Alexophulus returned to the vicinity of No. 8 and No. 9 center tanks and notified the Chief Officer, Nikolaos Andoniou, that the coffee was ready. He was told to go aft and get his coffee at which time Alexophulus departed the cargo tank area and went aft. Alexophulus observed the chief officer, Second Mate, K. Spetriotes, Pumpman Antonios Zebelis, and Able Seaman Desta Gebrehidin in the vicinity of No. 8 and No. 9 center tanks as he left the deck about 10 minutes before the first explosion. Alexophulus understood that the chief mate and second mate would go and have their coffee shortly after he left the scene.

There were no irregularities or problems associated with the cargo discharge when Alexophulus left the deck area. All cargo at that time was discharged except center tanks Nos. 2, 3, 8, and 9. No. 3 center tank had been secured just prior to Alexophulus leaving the deck. No. 8 and 9 center cargo tanks contained approximately 2 1/2 feet of cargo. The amount remaining in Nos. 2 and 3 center tanks is unknown. One cargo stripping pump was being used in the forward pumproom and one pump was being used in the after pumproom. The remaining cargo discharging was expected to be completed in about 1 hour.

25. An ARCO Terminal employee, Mr. Vain, while on shore a distance of about 400 feet from the M/V ELIAS, recalled seeing activity and what appeared to be a lit flashlight being moved about on the forward deck of the M/V ELIAS approximately 10 minutes before the explosion.

26. At about 2150 hours while Mr. Calafaty was in his car he observed persons coming out of the midship deck house with what appeared to be lit cigarettes in their hands. These persons appeared to be moving toward the ladder leading to the main deck. Mr. Calafaty shortly thereafter heard a loud hissing sound followed by a flash and explosion forward of the midship house. Mr. Calafaty stated that he left his car and witnessed another explosion after which he reportedly was struck by flying debris. He stated that after the second explosion the M/V ELIAS was completely engulfed in flame and blew apart.

27. Witnesses on board the M/V ELIAS confirmed that the first visible indication of an explosion was a fireball above the tank deck forward of the midship house. Witnesses recalled one to three explosions depending upon their vantage point and state of awareness.

28. Crew members on board the M/V ELIAS, except for the deck watch, were in their cabins or on watch on deck and in the engineroom. The first awareness of any difficulty was the violent explosion which threw the crew members to the deck. Most of the crew members in the after deckhouse found their way to the stern and upon seeing the flames on shipboard and in the water progressing towards the stern abandoned ship by sliding down the mooring lines on the port side and in some cases by falling into the water and swimming ashore. All crew members who were observed on the stern after the casualty survived except for Able Seaman Huseyin Aksu who was last seen falling from the mooring line into the water.

The survivors made shore at the lower limits of the fenced ARCO property. The survivors received no immediate assistance and found their way into the terminal. The actions of two unidentified occupants of an automobile which was parked alongside and downstream of the ARCO plant property were mysterious. Although these persons observed the explosion and fire they did not offer any assistance to the survivors as they made shore. None of the persons known to be within the forward deckhouse survived. The two persons on watch in the engineroom did not survive.

29. After the initial explosion a fire alarm was transmitted on the Philadelphia Fire Department fire box outside the guard house by ARCO Marine Terminal employees as the M/V ELIAS burned out of control. The Philadelphia Fire Department land units arrived on scene at about 2200. The first unit responded within 5 minutes of the alarm. Three subsequent alarms were sounded and a total of 16 pumper units and five ladder units were dispatched to the fire.

The land companies were seriously hampered in arriving at the scene of the fire because of the extremely narrow access road from the main highway leading to the ARCO Marine Terminal. The land companies were unable to start fire fighting operation because of a lack of hydrant water supply due to the closest fire hydrant at the ARCO facility being destroyed by the missiles from the exploding tanker. The nearest alternate hydrant supply was approximately 3/4 of a mile distant. The fire trucks, although fitted with pumps capable of lifting water from the river, were unable to use this equipment because the height of the lift from the river level was beyond the capability of the pumps.

The Philadelphia Fire Department's three fire boats arrived on scene and with shipboard pump and hoseline leading ashore provided a source of water from the Delaware River for the land company equipment on shore. The Philadelphia Fire Department utilized water to control and extinguish the fire. Foam units although available on scene were not used.

30. Radio emergency communications between the police and fire department land and waterborne units although effective were limited since Coast Guard, Navy, and municipal firefighting units on scene lacked a common communications channel.

31. The vessel, S/S EDWARD L. STEINIGER, docked at berth "B", ARCO Terminal, Fort Mifflin at 1753 hours, 9 April about 100 feet away from the M/V ELIAS in a bow to bow position. The vessel was fully loaded carrying crude oil from Punta LeBalmes, Venezuela. The vessel's draft was 38' 10" forward, 38' 05" mid, and 38' 10" aft. Two explosions, one at about 2140 and another following approximately 15 to 30 seconds later, were heard by personnel on board the STEINIGER. A third explosion was heard 10 to 15 minutes later.

Immediately after the first explosion the vessel's master, Captain Azzarito, looked out of a forward facing porthole in his state room which was about 50 feet above the water and corresponded to the approximate height of the bow of the M/V ELIAS. The master saw the top of the M/V ELIAS midship house clearly after the first explosion with flames behind it and coming around it. No fire was observed forward of the midship house. No fire was observed on the dock by any members of the S/S EDWARD STEINIGER crew except for the Third Mate Corrado Salvenimini who saw the cargo transfer hoses on fire.

32. Upon hearing the explosion Captain Azzarito ordered the cargo pumps shut down, all ullage opening and cargo valves closed, and the fire pump started. The general alarm was sounded and the crew was mustered. Three fire hoses were directed at the fo'c'sle as a preventive measure. The crew was assembled by the cargo manifold to disconnect the hoses in case the S/S EDWARD STEINIGER had to leave the dock. About 10 minutes after the explosion, Captain Santinelli (an ARCO supervisor who had been in the terminal building at the time of the explosion) ordered the crew of the S/S EDWARD STEINIGER onto the dock saying that if needed they could reboard the vessel. When the crew of the S/S EDWARD L. STEINIGER was ordered off the ship the engineering plant was abandoned with two boilers and associated machinery in operation on automatic control. Before leaving the engine room the watch engineer secured all but two burners in each boiler. The crew remained on the dock for about 15 minutes and went back aboard to disconnect hoses and slacken lines. The Tug TEXACO DIESEL CHIEF and Tug INTERSTATE TRANSPORTER towed the ship to midchannel to anchor.

33. The S/S EDWARD L. STEINIGER sustained above deck damage from flying missiles to cargo booms, king posts, cargo tank trunks, miscellaneous valves, pumproom and fo'c'sle door way, compressed air line, and the midship house forward bulkhead. There was no penetration of the main deck or hull plating which exposed or caused loss of any cargo.

34. Shortly after 2210 the towing vessel EXXON DELAWARE VALLEY moved the Dutch bulk carrier M/V MEDLLOYD CARVELL, which was imperilled by flames from the burning vessel, from Mantua Creek Anchorage. The vessel was towed down stream, and at about 2330 when it was considered safe, towed back and reanchored.

35. At about 2215 on 9 April the watch officer at the Philadelphia Navy Yard directed the YTB 759 with two fire fighters in addition to the crew to proceed to the scene of the fire on the M/V ELIAS to assist the Philadelphia Fire Department at Fort Mifflin. At 2234 the YTB 761 was dispatched to the scene of the fire with two additional firefighters. While both vessels assisted in combating the fire the YTB 761 also assisted moving the S/S EDWARD L. STEINIGER from the dock to a safe anchorage. The YTB 759 expended 1800 gallons of foam and the YTB 761 expended 560 gallons of foam. Both vessels returned to the naval base at 0253 on 10 April.

36. CDR. J. M. Mullen, Executive Officer of USCG Base Gloucester City, N.J., was the On Scene Commander following notification of the fire and explosion of the M/V ELIAS. Seven Coast Guard units, the CG 40412, CG 40408, CG 40470, CG 31001, CG 31019, USCGC CLEAT, and USCGC CATANARY from the U. S. Coast Guard Base, Gloucester City were directed to survey the scene, search for survivors, assist in firefighting, and control pollution. Coast Guard vessels assisted by illumination from the fire made a search for survivors up and down the river. No survivors or victims from the M/V ELIAS were recovered from the water.

The Coast Guard vessels on scene were equipped with fire extinguishers and pumps and a limited quantity of foam and assisted the fireboats in fighting the fire. During the firefighting operations off the stern of the M/V ELIAS the CGC CLEAT sustained damage to her propeller when a mooring line became fouled in the screw. The CGC CLEAT had to be towed away from the burning tanker. The crew had to abandon the cutter and were picked up by other Coast Guard units. There were no injuries sustained by any Coast Guard personnel on the scene. The CGC CLEAT was subsequently reboarded when the danger passed.

37. With the assistance of a Navy tug pollution prevention booms were deployed at the mouth of some of the more sensitive creeks in the area. Because of the intensity of the fire, booms were not deployed near the M/V ELIAS. It was estimated that 500,000 gallons (12,000 barrels) of cargo and bunker fuel were lost with approximately a 95-98 percent burnoff. Two commercial contractors, Underwater Techniques and Coastal Services, were contacted to assist in pollution control and cleanup. Pollution abatement continued until the hull of the M/V ELIAS was salvaged.

38. As a result of the explosion and fire on the M/V ELIAS pier "A" was extensively damaged with large sections of the concrete pier and pier supports completely blown out. Piping, electrical controls, and transfer hoses were either badly burnt, melted, or disrupted. The terminal building, some 400 feet from the M/V ELIAS sustained extensive blast damage to walls, ceiling, and lighting fixtures. The estimated cost of repairs to the ARCO facility is in excess of \$2 million.

39. The M/V ELIAS ultimately sank alongside the dock at berth "A". The bow section was relatively intact back to about frame 92 and floated at high tide. The bow was attached to the remaining portion of the vessel

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at the keel area. From the bow at frame 92 to the forward bulkhead of the after deckhouse at frame 50 the vessel was extensively damaged. The side shell was blown out on the port side from frames 92 to 82 and 80 to 50. The starboard side was also blown out from frames 92 to 82 and from 55 to 50. The main deck was opened and plating rolled back in most areas both forward and aft of the midship house and all tank bulkheads were either tripped over, ruptured, or missing. The tank section of the vessel below the midship house collapsed and the midship deck house settled into the hull and was covered with sections of the forward and aft main deck plating.

The midship house was damaged by fire and destroyed by the effects of the explosions in other parts of the vessel. The after section of the vessel from frame 59 aft, including the after deckhouse, although not excessively disrupted by the explosion was ravaged by the fire. The after section of the hull including the engine room space flooded and settled to the bottom of the Delaware River. The major portion of the tank deck was below the high water level and only a portion of the bow, midship house, and aft deckhouse remained above water.

40. On 5 April a tank vessel (the M/V CHRYSANTHY) in the process of unmooring caused some damage to the pier at berth "A" at the ARCO Terminal. This involved some derangement of the bumper system (a combination of steel girders and wood to absorb the movement of vessels against the pier) and bending of some conduits associated with the active cathodic protection system. Survey reports indicate that there was no evidence of protruding steel members that would have been able to contact vessels moored at berth "A" as a result of the damage. Dock maintenance personnel reported that the cathodic protection system on pier "A" was deenergized after the damage of 5 April.

41. The general electrical equipment on the ARCO pier at berth "A" was mostly of an explosion proof standard suitable for Class I Group D locations. Electrical equipment on the pier within 50 feet of the M/V ELIAS which was not rated as explosion proof was the rectifier for the cathodic protection equipment and a telephone in the control cab on the rig.

42. The M/V ELIAS arrived at Fort Mifflin with a full cargo of crude oil from the Bachaquero field in Venezuela. This crude can be characterized as a thick viscous liquid containing a high percentage of high grade asphalt used for road surfacing. The crude oil must be heated to 125°F. to expedite cargo transfer.

A chemical analysis of a composite sample of this cargo was routinely taken by the ARCO representative on 8 April. This analysis indicated that the cargo had an API gravity of 16.5 corresponding to a density of 7.9 lbs. per gallon at 60°F. The sample contained a quantity of low molecular weight aliphatic and olefinic light end hydrocarbon gases (methane, ethane, propane..., ethylene, propylene, etc.) dissolved in the liquid phase.

The crude oil on the M/V ELIAS contained a fairly high concentration of sulphur; 2.44 percent sulphur by the AR-328 Test which measures the total sulphur concentration. The percentage of sulphur found by the AR-328 Test includes hydrogen sulphide ( $H_2S$ ) in the liquid phase of the cargo. The presence of the  $H_2S$  in the crude oil magnifies the hazard of carriage since unlike most hydrocarbon vapors the gas phase may have a concentration of  $H_2S$  far in excess of measurements of  $H_2S$  in the liquid phase. The primary danger of high  $H_2S$  concentration in the vapor phase is the potential lowering of the autoignition temperature of the cargo vapors and lowering of the minimum energies which can produce ignition.

Crude oils containing  $H_2S$  can potentially build up iron sulphide by the corrosive action of sulphur compounds on mild steel. Iron sulphide is a black or brown colored material found in grainy, scaly, lumpy, or powder form. Deposits of iron sulphide can catch fire spontaneously when exposed to oxygen in the air. On ships used continuously in the carriage of high vapor pressure crudes, the hazards associated with pyrophoric iron sulphides arise when scale from cargo tanks and the gas vent lines is permitted to dry out and combine with oxygen in the air to cause combustion.

The commonly understood physical/chemical properties of crude oil and petroleum products which illustrate the hazards are the flashpoint and the Reid Vapor Pressure.

Flashpoint indicates the lowest temperature at which a concentration of vapors sufficient to momentarily support a flame are given off by an oil sample in a specific test. Flashpoint does not always mark the lowest temperature at which specific vapors given off by some crude oils can be ignited. The flashpoint test releases the more volatile vapors before the test procedure and a flammable concentration of vapors may exist in the ullage space of a vessel at temperatures below the determined flashpoint. The flashpoint of the crude oil cargo aboard the M/V ELIAS was determined as  $62^{\circ}F$  by Tag closed cup test.

The Reid Vapor Test (ASTM D323-58) is a closely defined test for characterizing the vapor pressure of a sample of petroleum liquid. A Reid vapor pressure is an equilibrium condition brought about by mechanical agitation and heating. A sample of liquid is introduced into a test chamber with the liquid to vapor ratio of 1:4. The whole container is immersed in a water bath and heated to some standardized temperature (usually  $100^{\circ}F$ ). After shaking the container to bring about equilibrium conditions rapidly the gage pressure is recorded in psia as the Reid vapor pressure (RVP) of the sample. The pressure gauge reading gives a close approximation of equilibrium pressure of the liquid at the test temperature and for the liquid to vapor volume of 1:4. The vapor pressure of a given petroleum sample will differ from its RVP due to cargo temperature differing from the test temperature and liquid to space volume ratio differing from 1:4.

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The test analysis of the sample indicates the RVP of the cargo aboard the M/V ELIAS to be 1.4 psia.

The vapor pressure of a specific crude oil under transportation conditions can vary significantly from the RVP. The RVP is taken at a specific temperature (100°F), therefore, if the crude oils are heated, the vapor pressure will differ from the RVP because of the ambient temperature conditions.

43. On 15 April divers employed by Underwater Technics, Inc., under contract to the Delaware County District Attorney's Office discovered two bodies beneath the water in the wreckage of the captain's salon of the M/V ELIAS, a woman and a teenage girl. The heads and necks showed signs of severe burns. Below the neck there was evidence of heat and burns but not to the same degree as the heads. On 16 April also in the captain's salon were found the body of a male and an older teenage girl. The heads and necks of these were also severely burned. The male was completely clothed while the girl's clothing was mostly gone. There were signs of lesser degree burns about the girl's body. The bodies were delivered to the Delaware County Coroner and were later identified as the Master, Andreas Antoniadis, Mrs. Matina Mentis, Joann Mentis, and Georgeen Mentis.

On 18 April and 23 April an extensive search was made of the remaining accessible parts of the vessel including the third mate's room, captain's cabin area, fo'c'sle area, and the ship's hospital. Attempts were made to gain entrance to the chief mate's quarters but entry was hampered by a jammed door. Attempts to enter this space by other means were not made because of a prohibition against open flames from cutting.

During this period of time a cleaning crew found a rib cage and miscellaneous parts of a body in the aft portions of the vessel which was above water. This person was not identified, however, a pathologist through X-ray and other tests was able to determine that the rib cage belonged to a male approximately 5' 7" tall.

On 16 April while divers were searching the captain's quarters they found the ship's deck log, the vessel's incoming correspondence file, and miscellaneous books and papers. All the documents were badly oil and water soaked with some charred around the edges. With the exception of a few pieces of incoming correspondence all letters and the ship's log were in the Greek language.

44. After the casualty two bodies surfaced within a mile of the wreckage of the M/V ELIAS. They could not be identified as members of the crew even though finger prints were lifted from each body. The owners were requested to provide a copy of the finger print records of the missing crew members on file in Greece. The finger print charts obtained were of poor quality and no identification could be made that the persons recovered were any of the missing crew members of the M/V ELIAS. The

final disposition of the bodies was handled by the Gloucester County Coroner's Office of New Jersey and the Delaware County Coroner's Office of Pennsylvania.

45. After the casualty parts of a metallic non-explosion proof three cell flashlight was found on the approach to pier "A" approximately 200 feet from the M/V ELIAS. The lens and batteries for the flashlight were missing from the case. The bulb was in place and not broken. All parts were coated with a black tar like substance. The owner or source of this flashlight bearing the trade name "SONCA" embossed in the cap was never identified.

46. On 25 March 1974, LTJG Ernest Blanchard of the Coast Guard Group, Southwest Harbor, Maine, visited the M/V ELIAS at Bucksport, Maine, to investigate a reported oil pollution incident. He went into the forward main cargo pumproom to investigate the nature of machinery derangement which reportedly caused the oil pollution incident. The master reported the port cargo/ballast pump had suffered a broken piston rod. Broken pump parts were observed in the vicinity. The pump had been repaired and was operating at time of the inspector's visit.

During this visit LTJG Blanchard noticed pitting and deterioration of the ballast piping and other wastage about the pumproom. The bottom two rungs of the ladder were rusted through and broken. The fire extinguisher in the pumproom was observed to be in a discharged condition and without a maintenance tag. A tour of the main deck indicated corrosion, rusting, and pitting of the cargo piping. Pools of condensate were noticed in areas around the steam heating piping.

47. A 24 hour advance notice of the arrival of a foreign vessel to the Captain of the Port is required by 33 CFR 124.10. On 5 April 1974, the ship's agent, Charles Kurz, Co., notified the Captain of the Port Philadelphia that the M/V ELIAS would arrive at 1200, 8 April at the ARCO Terminal.

Under message 080438Z Commander, Fifth Coast Guard District, Portsmouth, Virginia, advised the Captain of the Port Philadelphia that the M/V ELIAS requested assistance and reported having a fire on board at 2244 EDST. The master of the M/V ELIAS reported the fire extinguished at 2338 hours, no further assistance required and that the vessel was proceeding to Philadelphia, Pennsylvania.

An advance notice to the Captain of the Port of a fire or other abnormal condition which may jeopardize the vessel's safety or that of another vessel or facility in the port is required of domestic and foreign vessels bound for a port or place in the United States under 33 CFR 124.16.

48. The responsibility for the collection of data concerning fires rests with governmental agencies concerned with the regulatory function i.e., U.S. Coast Guard, Federal Aviation Administration, and state and municipal fire departments. Insurance companies and organizations

dedicated to the furtherance of the state of the art of fire protection i.e., National Fire Protective Association also collect fire cause data.

At present there is neither a coordinated nor a centralized collection of fire source information where the data is cataloged or available for exchange between interested agencies.

Major fire incidents and those having catastrophic results are usually thoroughly investigated and findings of the probable causes well published and distributed to interested agencies on a one time basis.

Minor fire incidents which are effectively extinguished by first aid fire apparatus or those of unsuspecting origin are not required to be routinely reported. Small fire incidents are not even superficially investigated and the probable cause of these fires is surmised in many cases due to the lack of information available.

49. Local law enforcement agencies suspected, based on information from an informant, that a cache of narcotics (marijuana) may have been on board the M/V ELIAS and that gunplay allegedly had taken place on the vessel while at the ARCO facility. This information was checked by local authorities without any concrete findings.

50. The possible relationship of activities of a suspect arsonist in a recent Philadelphia fire and the M/V ELIAS incident was investigated by the Department of Treasury, Bureau of Alcohol, Tobacco, and Firearms but the investigation was closed without any concrete findings.

51. Atlantic Richfield Company contracted with J. E. Brenneman Company to remove the wreckage of the M/V ELIAS. Between 1 April 1975 and 24 October 1975 J. E. Brenneman Company cut the hulk of the M/V ELIAS into sections and transported the sections by barge to the Arrdvark Shipbreaking Corporation in Chester, Pennsylvania. Arrdvark Shipbreaking Corporation cut up the M/V ELIAS for scrap and salvaged useful pieces of machinery and equipment. Salvaged sections of the M/V ELIAS were heavily silted and after cleaning were examined at the salvage site by Coast Guard personnel and surveyors representing ARCO. Select sections of the hull were obtained from the salvage company and retained by Atlantic Richfield Company. The Coast Guard representative obtained logs, personnel effects, and miscellaneous records for examination by the board and parties in interest.

The material held for the marine board was in custody of the Commanding Officer, Coast Guard Base, Gloucester City, New Jersey. The following is a summary of the post salvage survey:

a. The bow section to frame 92 was found relatively intact with little evidence of fire and explosions.

b. All cargo tank sections were extensively damaged with bulkheads tripped and badly distorted. The side shell sections were found blown at the approximate locations as noted in paragraph 39. Deterioration in the

tanks proper was found to be insignificant. Cathodic protector anodes, 3 feet, 2 inches square, were found installed on bottom longitudinals in most cargo tanks. The anodes were noted to be no more than 10 feet above the keel and all the anodes showed little wastage. Installation brackets for the anodes were sound.

c. The forward cargo pumproom was relatively intact. There was no evidence of machinery derangement. The position of valving reflected that the only equipment in operation at the time of the explosion was the stripping pump. The tank or tanks being pumped was not determined.

d. The after cargo pumproom was relatively intact except for the forward bulkhead which was ripped open and distorted outward at the forward starboard corner. The starboard main cargo pump was displaced from its mountings approximately 1 inch and the bulkhead to the starboard cofferdam was bulged and showed evidence of an explosive force. Piping was extensively distorted and displaced. The position of the steam supply valving indicated that the port cargo pump was in operation at the time of the explosion. The steam supply valve for the starboard cargo pump was found to be two turns open, however, there is no confirming evidence that the starboard pump was in operation at the time of the explosion. The starboard cargo pump in the after pumproom was disassembled and on examination was found to contain a number of nuts and bolts in the discharge head. There was no other indication of any internal damage or disarrangement to the starboard pump.

e. The after main machinery space except for being fire damaged was relatively intact. Much of the machinery including the main engines were in salvageable condition.

f. The forward and lower boundaries of the starboard cofferdam in No. 3 starboard tank were wasted and holed. One hole in the starboard cofferdam forward boundary approximately 1/2 inch in diameter was previously patched on the inside of the cofferdam by use of a doubler plate. The boundaries on the starboard void and the access cover were bulged out and split and showed evidence of an overpressure having taken place within the space.

Both recesses contained a 3 inch and a 4 inch diameter waste drainage piping which served the midship house. The waste drain piping penetrated the main deck in the midship house and ran outboard within the recess and sloped toward clapper valves in the side shell approximately eight feet below the main deck. Noticeable wastage and holes were evident in the drain piping in the starboard recess.

Ladder steps on the inside of the lower boundaries of the recesses were severely wasted to a feather edge at each step.

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g. The midship house was ravaged by fire throughout the navigation bridge deck, the upper bridge deck and salon on the lower bridge deck. Furniture and miscellaneous loose items were strewn about.

The body of the Chief Mate, Nicholas Andoniou, was found in the washroom in the chief mates cabin; the body of Second Mate, Elefterios Stefan, was found in the chief mate's salon; and the body of the Third Mate, Konstantinos Spetsiotis, was found in the passage outside the chief mate's salon. An unidentified skull was found in the fire ravaged section of the upper bridge deck.

Although the lower bridgedeck came to rest below the water line after the casualty, there was extensive fire damage mostly concentrated in the forward portion of the salon. The joiner bulkheads of wooden construction in the forward cabins were mainly charred by the fire.

Waste drain piping for the midship house which connected to the drain piping in the recesses was found to be holed in both the port and starboard sides on the main deck level. The waste piping on the port side was disconnected from the fitting near the main deck at frame 72 as though in the process of being repaired. The drainpipes at some sinks in the midship house were not fitted with water traps.

A vent system for air supply to the enclosed space (laundry and gyro room) on the main deck originated on the upper bridge deck near frame 79 on the port side. The vent duct was wasted and holed on the upper bridge deck near frame 79 and on the main deck outside the laundry gyro space near frame 78. There were open louvers in the vent duct to the laundry and gyro rooms. The vent motor located in the duct on the upper bridge deck was undamaged.

The washing machine was lost overboard during salvage and could not be examined, however, the fuse panel for the laundry equipment revealed that one fuse was missing from the washing machine circuit and the other fuse although loose, was in place. Fuses for the mangle and dryer circuits were missing.

52. An earlier version of this report was submitted on 19 April 1976. Subsequent to that date and before the report was approved, evidence of eye witnesses who observed pre-explosion flames, on the M/V ELIAS, unknown at the time of earlier inquiry, became known to the Board. Facts deduced from the depositions reflect the following:

a. A copilot on an approaching aircraft reported sighting a yellow to orange flame on the forward cargo deck of the M/V ELIAS in the area of No. 2 center cargo tank as he passed down the side of the vessel to the runway approach. He reported a wavering pencil-like flame which was estimated as 3 feet in diameter and 25 feet high. The estimated time of observation was at least 10 seconds to a minute in length. The witness also stated he saw several persons on deck during the time that he sighted the flame near No. 2 center cargo tank.

b. A pilot in another aircraft reported sighting a small orange flame on the forward cargo deck in the area of No. 2 center cargo tank as he passed the M/V ELIAS approximately 1/4 mile south in making his landing approach. He reported a small ball approximately 3 feet in diameter followed by a white flash. He passed the vessel without determining the source of the flash. The estimated time of his observation was approximately 10 to 15 seconds.

c. A witness on a vessel at the Mantura Terminal approximately 1 mile distant observed flames on the M/V ELIAS covering the length of the starboard cargo deck between the midship and aft deckhouses. The flames were pink to orange in color and estimated to be 2 to 4 feet in height and were observed 2 to 4 seconds prior to the explosion.

## CONCLUSIONS

1. The exact cause of the explosion or the exact location of the first detonation cannot be determined. One eye witness, flying near the M/V ELIAS prior to the first explosion, testified to seeing several persons on the fore-deck of the ELIAS. This cannot be substantiated by testimony of crew members or from the location of the bodies discovered. The Board concludes that the only persons on the cargo deck at the time of the casualty were the Pumpman, Antonios Zabelis and Able Seaman Desta Gebrihidhin as the other crew members associated with the cargo discharge were saved or the bodies of the others were recovered in locations which placed them away from the tank deck at the instant of the explosion. The person in charge of the cargo transfer operation in progress at the time of the mishap and who could provide some clues as to the chain of circumstances leading up to the sudden explosion unfortunately perished in the catastrophe.

2. The first detonation was one of major proportions and occurred suddenly and without forewarning to those onboard. The explosion which extended to both deck houses was so massive that the persons on the forward deck house were unable to take any evasive or protective action and perished in place.

The two subsequent explosions resulted from breached tank boundaries which exposed additional cargo tanks containing explosive atmospheres to the fire.

3. The Testimony of witnesses which is contradictory as to the location of the fire on the M/V ELIAS indicates that a flame or flame front was present on the deck of the M/V ELIAS preceding the explosion, and this flame most probably ignited vapors in the open tanks which caused the first and subsequent explosions. The hydrocarbon laden vapors were present in the cargo tanks and the vapors needed to mix with air to reach an explosive or flammable state.

The source of ignition of the vapors cannot be determined, however, several sources of ignition are known to have existed within the midship house and could have ignited cargo tank vapors. The Board considers the following probable causes of the first explosion:

a. Explosion in the recess in No. 3 starboard wing cargo tank

The salvaged hull sections in way of No. 3 starboard wing tank revealed that the starboard cofferdam which extended under the main deck was bulged and split, indicating that an overpressure had taken place in this void before any explosion occurred in No. 3 starboard wing tank. It is concluded that if a detonation of significant magnitude occurred within No. 3 starboard void, this would have set off an explosion in No. 3 starboard cargo tank and the first explosion. Since this damage is closely related to the location of the fire incident at sea, special significance must be attached to all fittings in this area.

The plating of the void was deteriorated and would permit ignitable vapors and/or liquid cargo (when the liquid level in No. 3 starboard wing tank was sufficiently high) to pass through the deteriorated and holed plating into the starboard void. This deteriorated condition of the plating apparently was known to the shipboard personnel since at least one double (patch) plate was found to be installed.

There are two possibilities that may have occurred which would result in an increase in pressure in the No. 3 starboard tank. One possibility is that after discharge the tank ullage opening was closed and the heating coils were left on. A second possibility is that a massive increase in vapor pressure resulted from a broken steam line in No. 3 starboard tank.

Any buildup of pressure within No. 3 starboard tank would have tended to equalize through the holed cofferdam boundry. A buildup of pressure within the cofferdam would have caused the trapped vapors to seek an escape route.

The drain soil piping leading overboard passed through the cofferdam and discharged overboard through clapper valves at the side shell plating. The soil piping was holed both inside the cofferdam and on the main deck level inside the deck house and could have provided the route to carry the vapors to the interior of the midship house, shelter deck area, the cabins and deck toilet space. A gooseneck vent connected to the trunk of the cofferdam in No. 3 starboard wing would also have allowed vapors caused by an over pressure to escape to the main deck on the starboard side of the midship house. Vapors in the vicinity of the midship house could have traveled to the interior through the holes found in the wasted ventilation ducting.

Many sources of vapor ignition including the gyro equipment on the main deck, the hot plate in the officer's pantry, the lighting and other convenience accessories, and smoking by crew members who were present in the forward deckhouse spaces. The relative intact condition of the midship house and the furnishings preclude a finding that a major detonation occurred within that space. The most probable chain of events would have been for the vapors to provide a trail for a flame front to enter the soil piping in the cofferdam where the detonation occurred.

A chain reaction resulting from breached cargo tank boundaries would have produced the massive instantaneous initial explosion.

In the fire at sea episode, witnesses described the plume effect of the flame vapors around No. 3 starboard cargo tank ullage opening which would indicate that the tank was pressurized and the vapors ignited upon reaching the atmosphere. The plume effect would also tend to support a finding that the pressure relief valve element on No. 3 starboard tank was either malfunctioning or was closed and permitted a high vapor pressure to exist within No. 3 starboard tank. Such a malfunction of the pressure relief valve while the vessel was at the ARCO Terminal coupled with the tank ullage opening being secured would have resulted in excess pressures in No. 3 starboard tank.



b. Explosion in the cargo tank

Since flames were sighted from an aircraft in the vicinity of No. 2 cargo tank, there is a strong possibility that the initial explosion may have occurred within one of the empty or near empty tanks in process of being stripped. The steam heating coils to the cargo tanks had been in use during the entire period of discharge. Most probably the heating coils to center tanks No. 2, No. 3, No. 8, and No. 9 were still activated at the time of the explosion. One or more of the heating coil branch valves to other tanks may have been ineffective in controlling the flow of steam or the deck crew may have failed to secure the heating system to a tank when it was empty.

The continued operation of the heating coils in the cargo tanks after the liquid fell to the level of the heating coils would expose residue oil on the coils and hydrocarbon vapors within the tank space to the higher heat source, causing the vapors to be additionally heated and distributed by convection. The vapor and gas temperature would reach the steam supply temperature of approximately 300° F if the steam supply was near 100 psi as reported.

The report of a loud hissing noise just prior to the first explosion could have been caused by steam escaping from a ruptured steam heating line on deck, in the pumproom, or a heating coil in a cargo tank. The escaping and swirling steam in a vapor laden cargo tank could accelerate the build-up of a static charge, and in addition mix the vapors providing an ideal explosive atmosphere. Although a similar phenomenon could occur during tank cleaning operations, there is no evidence that any tank cleaning or tank washing was in progress prior to the time of the explosion. Movement between two dissimilar bodies or mediums produces and stores an electrical charge. When the quantity of stored electrical charge accumulated and a sufficient difference of potential between the vapor mediums or the hull existed, a discharge in the form of an electrical spark of sufficient energy could have resulted and produced vapor ignition.

A bonding cable was installed between the ship's cargo manifold and the hose rig crane on shore and would have reduced the buildup of electrical potential between the ship and the shore. The bonding cable would have little influence on the static charges built up within individual cargo tanks or pumproom space boundaries.

Whether a flame screen was in No. 2 cargo tank ullage opening is not known, however, even if a flame screen was in place, it would have become ineffective once heated from a flame burning above it. The flame would have passed into the tank and ignited the vapors within and caused the explosion once the proper air vapor mixture was reached.

Vapors from a ullage opening of one of the forward cargo tanks in the final stages of discharge could have drifted to starboard and aft with the prevailing wind, and entered an opening in the midship house and come in contact with a source of ignition normally present. A flame

front could have then traveled to the ullage opening igniting vapors being emitted from the tank. This would have been consistent with the report of a witness who reportedly heard a hissing sound prior to the explosion.

c. Explosion in the pumproom

The M/V ELIAS was in the final stages of cargo discharge with all tanks empty, except for some cargo remaining in No. 2, 3, 8, and 9 center tanks, about 10 minutes before the first explosion. There is a conflict in the testimony as to the time that the cargo discharge would be completed. The able seaman who left the deck just prior to the explosion was told that the discharge would be completed in about an hour. The ARCO dockman was advised by the chief mate that the completion would occur about 0200.

Although the precise time of cargo completion cannot be resolved, it is concluded that the cargo discharge may have been progressing at a faster rate than anticipated when the report was made to the dockman. Since a pump was being used in each pumproom, it is very probable that cargo was being discharged from both forward and after cargo tanks.

The testimony is vague as to normal shipboard routine or the number of times the pumpman or other persons went into the cargo pumprooms to check on the condition of the operating machinery during a normal discharge or during the period immediately preceding this casualty.

There is no direct testimony that there was cargo or cargo vapors in either cargo pumproom. However, even a small leakage of cargo from around the pump glands with the addition of heat from the steam supply could have produced a sufficient release of vapors to place the atmosphere within the explosive range.

The port reciprocating pump in the after pumproom was being used to pump cargo from the tanks. The starboard cargo pump and stripping pump were secured. The evidence of explosion damage to the hull structure and displacement of the starboard cargo pump in the after pumproom indicates that a detonation occurred in that space. Whether this explosion was the primary of subsequent detonation cannot be determined.

The possible ignition of vapors in the pumproom could have resulted from falling object, deficiency in the electrical wiring, lighting components, static electricity phenomenon, or incendiary device.

The stripping pump in the forward pumproom was in operation, however, in view of absence of any evidence of explosive damage or derangement

of machinery, there is little probability that the original detonation occurred in the forward pumproom space.

4. The board considered the following ignition sources may have been present and contributed to the casualty:

a. A three cell nonexplosion proof flashlight similar to the one found on the pier could under special circumstances provide the electrical energy sufficient for ignition of explosive vapors. Under test conditions the electrical potential of the three "D" cells is insufficient to set off a vapor ignition unless the bulb breaks and the explosive vapors are exposed to the incandescent heat of the filaments. Since the glass envelope of the three cell flashlight found on the pier was found intact ignition vapors by electrical energy or the incandescent heat from the flashlight if the flashlight was used on the ELIAS is considered remote.

b. An anode of certain material falling from a critical height to the bottom of a cargo tank and striking a steel member could create a source of spark ignition. The anodes in the cargo tanks of the ELIAS upon salvage were not observed to be installed any higher than approximately 10 feet above the bottom of the vessel. Neither the anodes nor their holding brackets appear to be wasted. Therefore the probability of falling anodes as a source of ignition is considered remote.

c. The presence of a high percentage of sulphur in the Bachaquero crude oil cargo probably contributed to the release of sulphides, primarily  $H_2S$ , into the vapor space. A combination of  $H_2S$  and the light end vapors which were present could, under favorable conditions, produce a mixture of gases with a lower autoignition temperature or which would require a lower amount of energy to produce ignition. Such a mixture was probably present while the vessel was at sea and also in the process of discharge and could have produced conditions favorable for autoignition or ignition from a smaller energy source.

d. The buildup of iron sulphides on the surface of the tanks and in the interior of the vents of the M/V ELIAS is a possible source of autoignition. When iron sulphides become dry or are exposed to the atmosphere autoignition may occur. The buildup of iron sulphides could have occurred over an extended period of time during which the vessel carried high vapor pressure cargo with high sulphur content. The nature of the previous cargoes carried was not determined and therefore any extensive exposure to high sulfur cargoes is unknown. The presence of iron sulphides is considered to have low cause probability.

e. Escaping steam or air at high velocity coming in contact with petroleum vapors in the atmosphere or materials coated or soaked with oil could produce conditions favorable for spontaneous ignition. Lagging

on steam and water piping saturated with oil products could, either alone or in combination with an escaping gaseous medium, create a source of spontaneous ignition. Whether there was such a lagging or insulation on piping within the pumproom or adjacent to the cargo tank openings was not determined. Insulation, if present and combined with escaping steam or air, would have been a possible source with moderate probability.

f. Smoking in hazardous areas could have provided a spark or ignition necessary to cause the explosion. Eye witness testimony by a watchman on shore reflects that persons were seen smoking after leaving the vessel's midship house and prior to the explosion. It is improbable that a crew member of a tank vessel would violate such a well established safety precaution prohibiting smoking in a hazardous area. There is a distinct possibility that areas in the midship house normally certified as safe for smoking may have become contaminated by vapors without having been detected as indicated in conclusion 3.a. Smoking in any of these areas contaminated by vapors finding their way into the midship house by wasted ventilation ducting and soil pipes could have provided the ignition source. Persons expected to be in the midship house, except for Maria Mentis, are accounted for. Even though Maria Mentis could have been unfamiliar with shipboard restrictions concerning spark producing devices, the probability is remote that she was the originator of the source of ignition because she was reportedly a non-smoker.

5. The most probable cause of the fire at sea on 7 April was the ignition of vapors under pressure escaping from the cofferdam deck vent and from around the ullage opening of No. 3 starboard cargo tank. Although the exact cause of ignition was not determined, ample sources were available in the immediate vicinity of the deckhouse.

In transit the ullage of No. 3 tank was small with the tank nearly filled to capacity. The expansion of the liquid in No. 3 starboard tank as it was being heated would have reduced the effective ullage volume and thereby placed the vapors in the ullage space under greater pressure.

The normal venting of excess pressures in No. 3 starboard cargo tank should have occurred through the vent system at the designed pressure of the pressure vacuum relief valve of 1.99 psi. The designed 4 inch vent line was of sufficient size to carry off the excess vapors as the tank was being heated.

The venting of the vapors from around the closed ullage opening would support a conclusion that the ullage space of No. 3 starboard cargo tank was under pressure higher than the 1.99 psi and further, that the excess in pressure was not being relieved through the P.V. valve either because the valve was inoperative, closed, or operated

with severely reduced flow. The vapors from No. 3 starboard tank, under pressure, found their way through the holed cofferdam bulkhead and some of the vapors vented and probably ignited as they were released at the main deck gooseneck opening. These vapors probably ignited and caused the condition noted by the Coast Guard inspector that a portion of the bulkhead was charred, both on the inside and the outside, indicating some intense heat concentrated in that area. A portion of the vapors probably found their way out of the vessel through the overboard discharge and others backed up into the midship deckhouse as noted in conclusion 3.a. The exact nature of the combustibles in the midship house which caught fire could not be determined, however, the partially burned covering on a bag of sawdust observed by the Coast Guard inspector is one of the probable fuel sources.

6. The fire incident at sea on 7 April and the explosion on 9 April were related. However, the actual cause of the fire at sea was not fully evaluated by shipboard personnel. There probably was a significant backup of cargo vapors into the midship house, however, shipboard personnel were either unaware of the presence or minimized the vapor attributing this to the nature of the cargo. The lack of awareness on the part of crew of the explosive vapor characteristics, in all probability, was influenced by the fact that the cargo had to be heated in order to be kept viscous. The Coast Guard COTP representatives who investigated the incident were unaware of the structural deficiencies which were later discovered in the cofferdam and soil piping and probably their attention was diverted more into searching for probable sources of the fire than they were in determining the exact cause.

7. A significant quantity of cargo and bunker fuel spilled from the damaged M/V ELIAS at the time of the accident and continued until all parts of the vessel were covered, polluting the Delaware River in violation of the Federal Water Pollution Control Act, 33 USC 1321(b). The fire which followed the intensive explosion on the M/V ELIAS was fueled by the remaining cargo of Bachaquero crude oil onboard. As the cargo was released from the ruptured cargo tanks, the oil ignited on the dock and ignited the hose rack at berth "A".

8. The following persons died aboard the M/V ELIAS as a result of the explosions and fire: Captain Andreas Antoniadis, Mrs. Marina Mentis, Georgeen Mentis, Joann Mentis, Chief Mate Nicholas Andoniou, Second Mate Kostantinos Spetriotis, Third Mate Eletherios Matas. Able Seaman Desta Gebrhidhin died as a result of the casualty and his body was found on the approach to the pier where the M/V ELIAS was moored.

9. The visitor Maria Mentis, Pumpman Antonios Zabelis, Able Seaman Huseyin Axsu, Fireman Salama Elhadidy, Fireman Enver Mehmet who are missing or if recovered cannot be identified are presumed to have died as a result of the explosion and fire onboard the M/V ELIAS.

10. Although the presence of the visitors (the Mentis family) onboard did not appear to contribute to the cause of this casualty, their presence may have been in violation of established safety precautions. Title 46 CFR Part 35.30-1(b) requires the posting of a warning sign (no open lights, no smoking, no visitors) at the gangway during cargo transfer operations. The prohibition concerning no visitors is obviously intended to restrict persons unfamiliar with the hazards attendant with cargo transfer operations from introducing hazards aboard a vessel.

The prohibition concerning no visitors imposed by ARCO on vessels owned or chartered by them reflects strict enforcement and interpretation of "no visitors". The master of the M/V ELIAS brought his visitors aboard and presumably supervised their activities while they were aboard. The present guidelines as contained in the regulations are too vague and do not ensure that visitors or shoreside persons engaged in the business of the vessel are adequately safeguarded or that these persons are sufficiently supervised so as not to inadvertently jeopardize the vessel.

11. The M/V ELIAS was in the final stages of cargo discharge and all cargo tanks would have been full of vapors at various mixtures ranging from above the upper explosive limit to below the lower explosive limit. The vapors in the tanks at the moment of the initial explosion contributed to the massive damage in the cargo tank spaces. The installation of a gas inerting system for the protection of cargo tanks as they were discharged would have materially reduced the catastrophic effects of this casualty.

12. The board noted the following conditions at the Atlantic Richfield Terminal which, although they did not contribute to the cause or the severity of the casualty as being worthy of special mention:

a. Some visitors were able to freely enter the facility and board the M/V ELIAS during the period of cargo discharge without being observed by the gate guard.

b. ARCO's instructions to dock personnel concerning their duties during cargo transfer operations and emergency procedures were in the main oral and not clearly defined.

c. The dockman (second operator) was absent from his post on the hose rig on the dock during portions of the discharge operation without being relieved as required by ARCO Terminal instructions. There was no terminal employee in close proximity of the M/V ELIAS for several minutes prior to the first explosion who would be in a position to render assistance if such a request by personnel aboard the M/V ELIAS was initiated.

d. Terminal maintenance personnel installed nonexplosion proof electrical equipment (telephone and cathodic protection rectifier) on

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the dock which was not consistent with the integrity of other electrical installation which apparently met an explosion proof standard.

13. The failure of the master to directly notify the Captain of the Port, Philadelphia, of the fire incident aboard prior to arrival did not meet the intent of 33 CFR 124.16. The fact that the master advised the Coast Guard, Portsmouth, Virginia, by distress message of the fire incident and incidental to the cancellation of the emergency, notified the Coast Guard that he was proceeding to Philadelphia can be considered mitigating since the Captain of the Port was provided a copy of the distress message traffic for information. The Captain of the Port knowing of the fire incident at sea, should have examined the vessel prior to permitting the discharge of cargo.

14. There is no evidence that any personnel of the Coast Guard or any government agency contributed to the casualty.

15. The results of this casualty would have been far more extensive were it not for the availability of the fire boats from Philadelphia and the U.S. Navy tugs fitted with fire fighting equipment since the accident occurred at a facility located in a remote section of the Delaware River waterfront which was difficult to reach by land units. Further, complications of the shore fire main being damaged by missiles from the exploding vessel deprived the fire fighting units of an available water supply. Although there were no prearranged port disaster control plans covering such an incident, the cooperation and coordination between the federal and local governmental agencies effectively minimized the pollution and hazardous consequences of this casualty.

The outstanding performance of the Philadelphia Fire Department in the extinguishment of the fire aboard the M/V ELIAS and the ARCO Terminal is deserving of special recognition.

16. The crew of the S/S EDWARD L. STEINGER and the dock crew, Captain Santonelli, Mr. Vain, Mr. Winders, and Mr. Chambers acted in an admirable and heroic manner and their timely actions in disconnecting and moving the SS STEINGER from the dock to a safe anchorage while the M/V ELIAS was afire and experiencing minor explosions reduced the effects of this casualty. Their actions are worthy of special recognition.

17. Captain Simonson and the crew of the uninspected towing vessel, DIESEL CHIEF, acted in a heroic manner in their actions to combat the fire on the M/V ELIAS. In an attempt to protect the S/S EDWARD L. STEINGER from the danger of the fire they moved in close to both vessels and directed a hose stream on the bow of the STEINGER till such time as the vessel was free from the dock. They then assisted in moving the STEINGER to a safe anchorage. The actions of the tug crew are worthy of special recognition.

The efforts of the personnel on the U.S. Navy vessels YTB759 and YTB761 were timely and effective in combating the fire on the M/V ELIAS and worthy of special recognition.

18. The information being received through required casualty reports of minor incendiary incidents occurring on tank vessels and those carrying hazardous materials are not adequate for obtaining complete data on fire risks being experienced on inspected vessels. The current required reports cover those incidents which result in the loss of the vessel, loss of life, or serious injury or property damage in excess of \$1500. In the instant case, the fire episode at sea would not have come to the attention of the Coast Guard or other government agencies except for the fact that the ship initiated a distress message. The investigation of near miss type fire incidents, which do not result in a reportable casualty, is necessary for regulatory agencies to fulfill their responsibility of providing adequate safe guards for carriage, containment, and transfer of hazardous commodities.

19. The true vapor pressure and flash point of mixed petroleum products and crude oils carried aboard tank vessels may vary from the values obtained by the Reid vapor pressure and flashpoint tests under laboratory conditions. This may be due to the small sample size with the resultant loss of some volatile components being tested under different temperatures, or vapor space to liquid volume relationship which may exist under actual shipboard conditions. The present regulations appear to be inadequate in identifying and providing proper safeguards for possible unknown hazards associated with light ends in the vapor space during carriage, transfer, and tank cleaning operations of vessels carrying mixed, spiked, or blended refined products and all grades of crude oil cargoes.

20. The circumstances associated with this casualty and the fire at sea incident prior to arrival at Philadelphia indicate crude oil cargoes may contain chemical compounds which, either in combination with other compounds or with structural materials, can form a reactive secondary compound. These compounds are either in themselves susceptible to autoignition or may lower autoignition temperatures.

21. That a central exchange for coordination and classification of information concerning all fires, including fire incidents and those which can be considered of unusual origin aboard vessels in a transportation mode and port related facilities should be established. This centralized data and fire incident information could be used to identify high risk areas and provide a positive method of evaluating the sufficiency of present standards as they relate to fire protection and prevention.



22. That although the testimony of the witnesses, who made aerial and ground observations, when interviewed three years after the casualty was detailed, it was not considered as determinative as may have been if they had been interviewed just after the incident. Their testimony is valuable, however, in that it provides a clue of the presence of a fire on deck prior to the first explosion.

There is a conflict as to the location of the flames as observed by the witnesses. However, the Board places more weight on location indicated by the aerial observers because of their vantage point and distance of the observations.

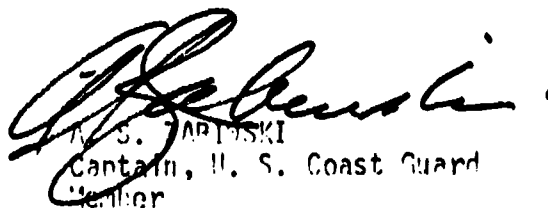
## RECOMMENDATIONS

1. That an increase in scope and frequency of examination of all tank vessels transferring hazardous materials in U. S. ports be initiated to ascertain if maintenance practices, operating procedures, or shipboard safety procedures as required by the current regulations are being adequately followed. Determine if the present regulations are adequately providing safeguards against hazards at terminal facilities during transfer operations.
2. That procedures for the reporting of fire incidents onboard all inspected vessels and foreign vessels scheduled to arrive in ports of the U. S. and while in U. S. territorial waters be initiated. The Coast Guard should establish a central clearing house for fire source data from inputs received from all shipboard, marine transportation, and port related fire investigative reports. The central collection of information could be used to provide data and check on the effectiveness of existing statutes and regulations governing the construction of vessels, transportation, and transfer of hazardous commodities.
3. That tank vessels carrying crude oil unrefined or skiked petroleum cargoes be required to be designed, and operated to provide safeguard against the highest risk volatiles which may be contained within the crude oil or cargo mixture being carried.
4. That the wording of regulations covering visitors on tank vessels be clarified. The regulations should prohibit uninitiated persons from going aboard tank vessels and require positive supervision by ship's personnel of persons who may be permitted on board during the hazardous times of cargo transfer.
5. That the sudden and massive detonation aboard the M/V ELIAS supports a recommendation that all tank vessels of significant size be fitted with a inerting system in the cargo tanks. The benefits in vessel safety to be gained by the proposed changes to the rules and regulations for tank vessels, incorporating the provisions of IMCO resolution A.271 (VIII) requiring an inert gas system for the protection of cargo tanks on crude oil carriers of 100,000 DWT and crude oil combination carriers over 50,000 DWT, is supported by the findings of the board. The board, however, recommends that a gas inerting system be required on all tank vessels of over 20,000 DWT carrying crude oil cargo.

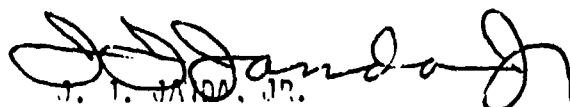
5. That independent tests be conducted to evaluate the validity of laboratory flash point and Reid vapor pressure test results as a means of identifying the hazards associated with petroleum cargo and petroleum vapor characteristics as they exist in a shipboard environment.



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